



*MILSATCOM Briefing
National Defense Industrial
Association (NDIA)
17 April 2007*

**Brig Gen Ellen Pawlikowski, Commander
MILSATCOM Systems Wing**



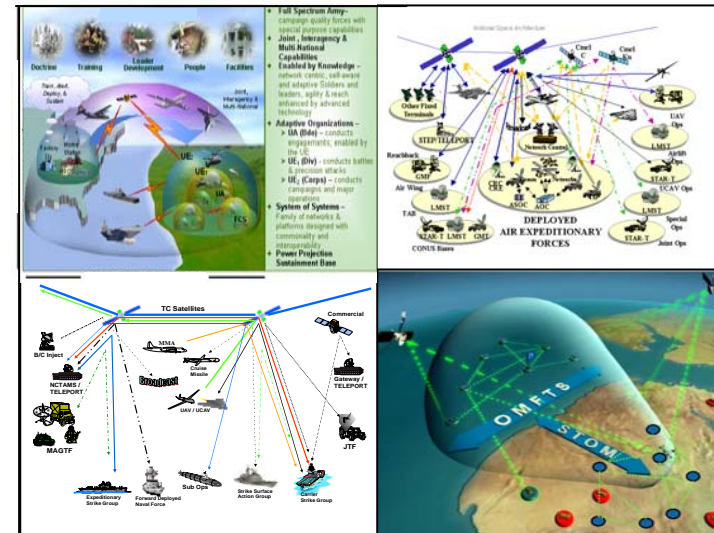
Transformational Satellite Communications System (TSAT) Description

- **Transforms satellite communications (SATCOM)**

- Extends DoD ground-based Global Information Grid (GIG) network to deployed and mobile users
 - Implements worldwide networking based on Internet Protocol
 - Laser communications (huge capacity gains)

- **Enables service warfighting visions:**

- Mobile battle command on the move
 - Current systems force comm-on-the-pause, or -stop
- Shared situational awareness
 - Red/blue force tracking; real-time intel
 - Complete sensor-to-shooter (through C2) capability
- Collaborative, offensive-oriented planning
 - Enables dynamic/high-tempo operations
- Provides assured command & control to strategic forces
- Linchpin for 21st century net-centric warfare
 - Communicate as a joint networked force





Military Satellite Communications

1960 - 2015

Protected Communications

Anti-Jam Waveform
Comm in nuclear environment

Anti-Jam Antenna



4X



40X



400X

TSAT



WHAT'S NEW

- Internet-like connectivity— Responsive
- Comm-on-the-Move to Support Small, Mobile Units
- Optical Band to Support ISR
- Increased Capacity all-around

4000X

2000X+

2000X

Ka-band ISR

Wideband Communications

X-band

Defense Satellite Communications System "DSCS I"



1X

DSCS II



60X

DSCS III



100X

DSCS III SLEP



250X

WGS



1500X

700X

1960

1971-1979

1982-1997

1994-1995

2000-2003

2001-2003

2006

2008

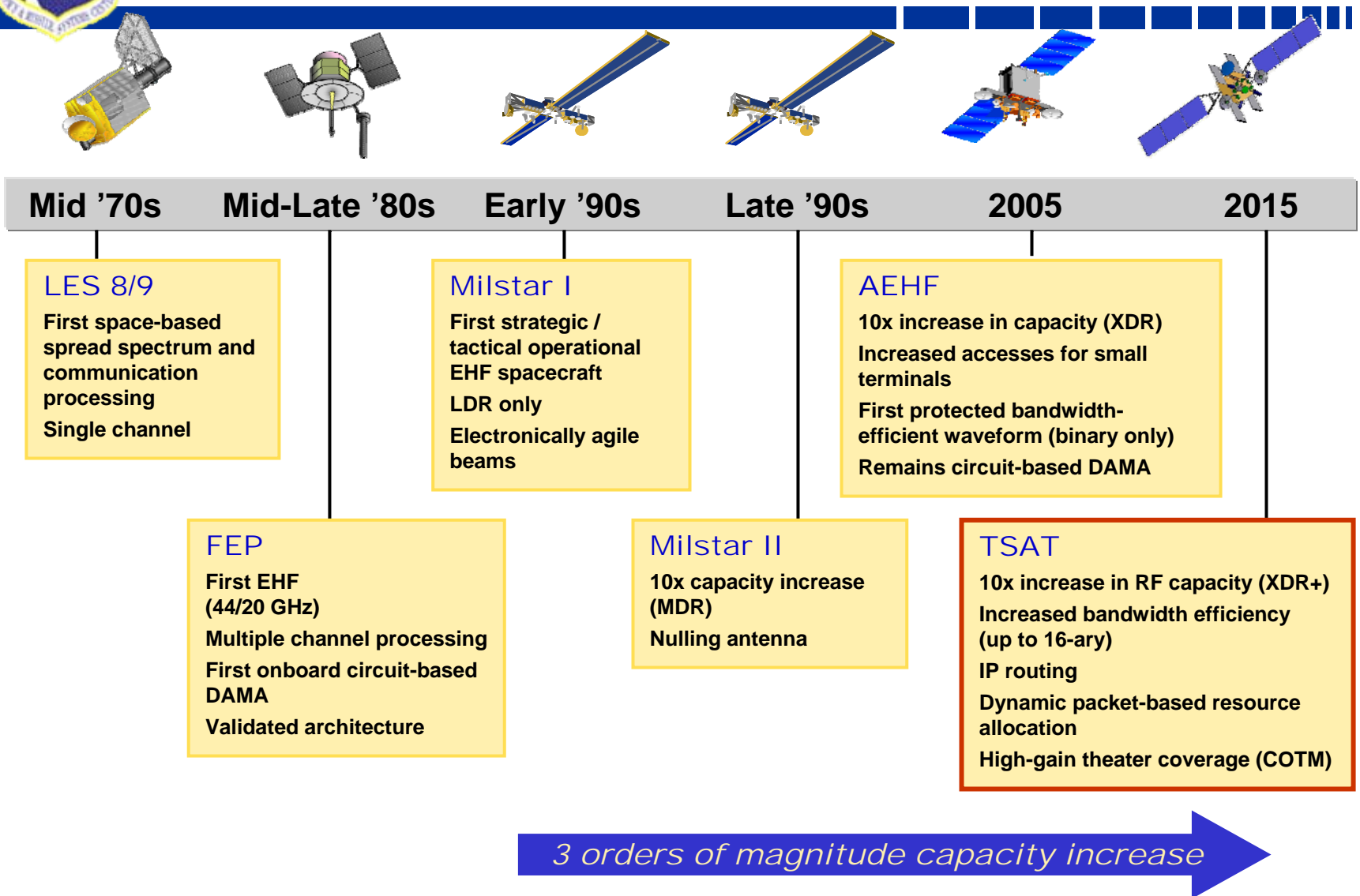
2015

Continuous Capacity and Protection Improvements: Being Responsive to our Warfighter Needs



Evolution of Onboard Signal Processing for Protection and Connectivity

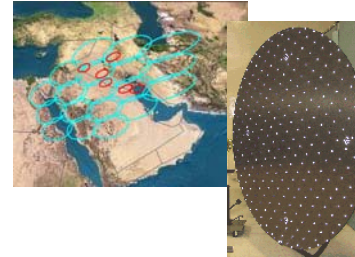
Highly Robust → Wide Bandwidth → Efficient





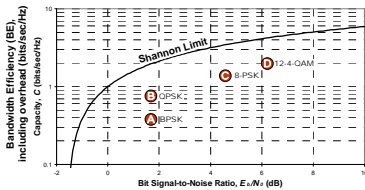
TSAT Critical Technologies

- Battle Command On the Move (BCOTM)

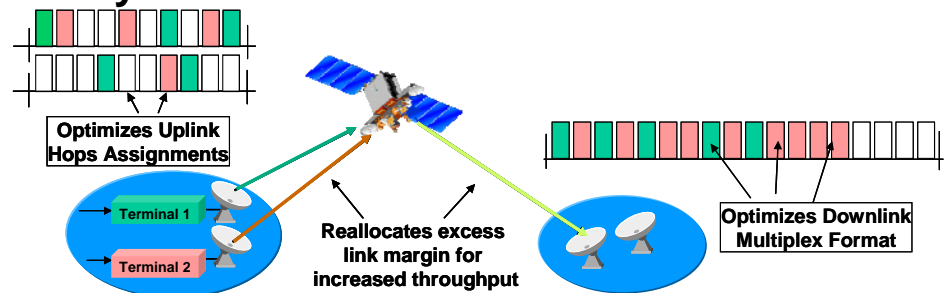


- Next Generation Processor/Router

- Bandwidth Efficient Modulation

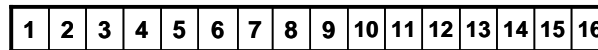


- Dynamic Bandwidth Resource Allocation



- Transec

COVER



16 independent uplink cover keys per satellite

Frequency Hopping

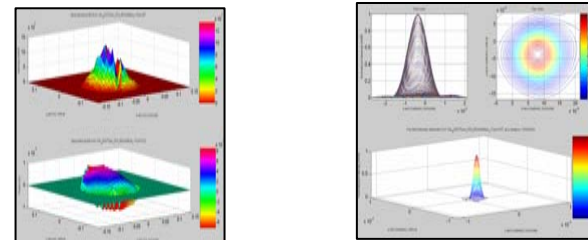


Two independent uplink patterns per satellite

- Space HAIPE

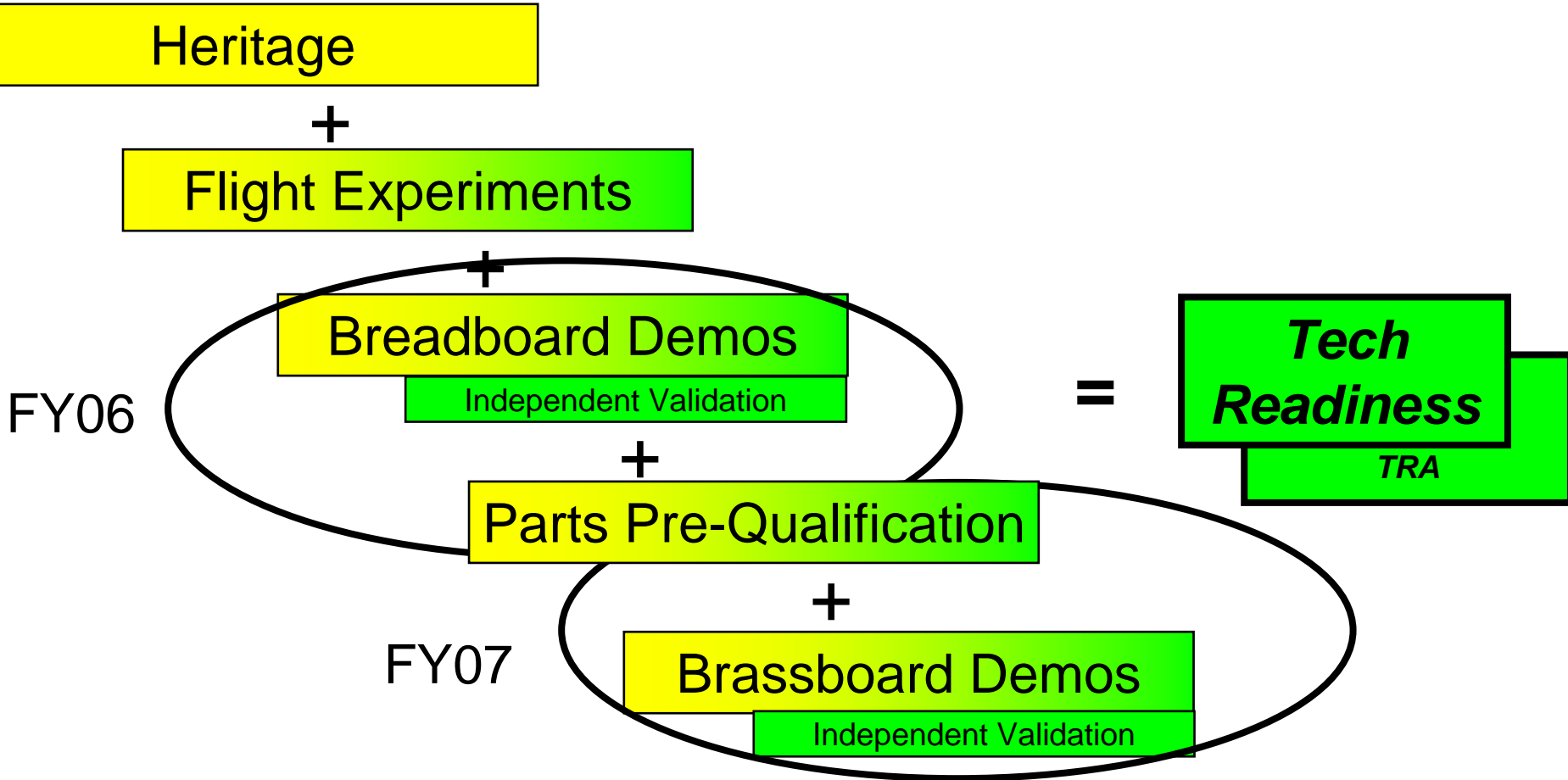


- Lasercom





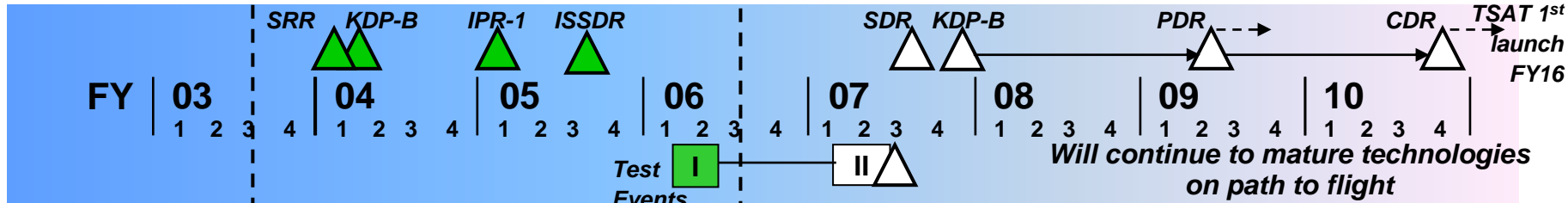
TSAT Definition of Technology Maturity/Readiness



Multiple activities used to establish tech readiness



TSAT Technology Readiness Level (TRL)



Battle Command on-the-move (BCOTM) Antenna

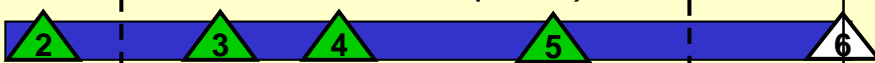


Bandwidth Efficient Modulation* (I.e. XDR+)

NGPR



Dynamic Bandwidth Resource Allocation (DBRA)



TRANSEC



Information Assurance

Space HAPE



Lasercom (10 Gbps/wavelength)



TRL-6

Key technologies (NGPR and Lasercom) verified via independent, government controlled test environments

- Test Event I (Nov 2005 – Mar 2006) - Breadboard

- Lasercom (LCT-1)

-- Waveform compatibility/perf at 10/40 Gbps

-- PAT (pointing, acquisition, tracking)

- NGPR (NGPR-1)

-- XDR+ waveform interoperability

-- Signal timing/tracking, data framing

- Test Event II (Nov 2006 – Feb 2007) - Brassboard

- Lasercom (LCT-2)

-- Signaling interoperability/perf at 2.5/10/40 Gbps

- NGPR (NGPR-2)

-- Integration of advanced signaling (XDR+) with IPv6 networking and DBRA

Key technologies will be demonstrated to TRL-6 by KDP-B

HAPE: High Assurance Internet Protocol Encryption

ISSDR: Interim Space Segment Design Review

OSVS: Optical Standards Validation Suite

NGPR: Next Generation Processor Router



Maturation Example: Lasercom

Heritage



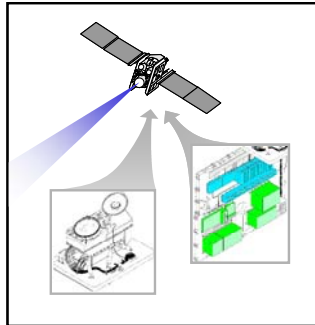
**LITE-2 EM
(Fiber-Based)
1990's**

Introduction of commercial parts

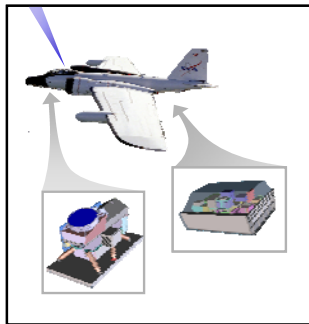
- Leverage large-scale manufacturing processes

Pre 2000

Flight Experiments



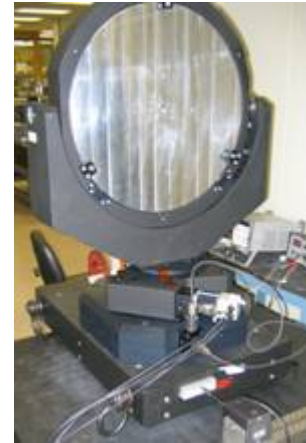
**Lasercom Experiment
(GeoLITE, 2001)**



**Airborne Laser Experiment
Alex Demonstration (2002)**

2001/2

Breadboard



2005

Parts Prequal

Key components/subassemblies

- Optical fiber
- Optical & RF Filters
- Optical & RF Modulators/Demodulators
- Diode transmitters/receivers
- Optical switches
- Interferometers
- Couplers/isolators

Vendor development and major Environment Testing (examples)

- Failure modes and Effects Analysis (FMEA)
- Thermal temperature cycling
- Vacuum
- Vibration
- Mechanical Shock
- Total Dose
- Prompt Dose /SEU

2006

Brassboard

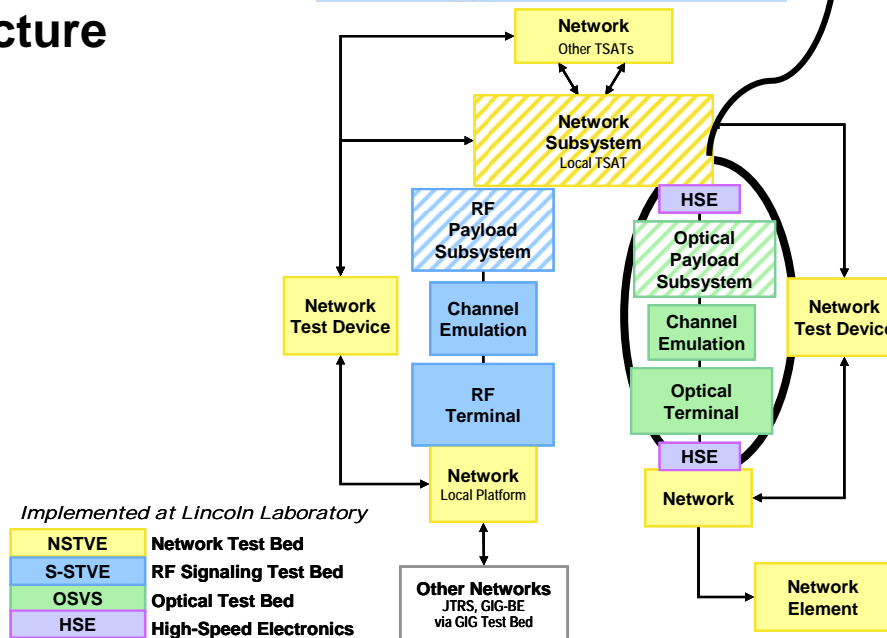
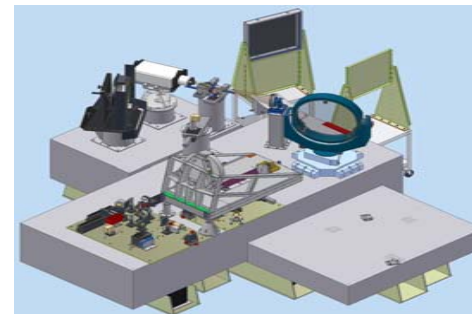


2007



Independent Validation

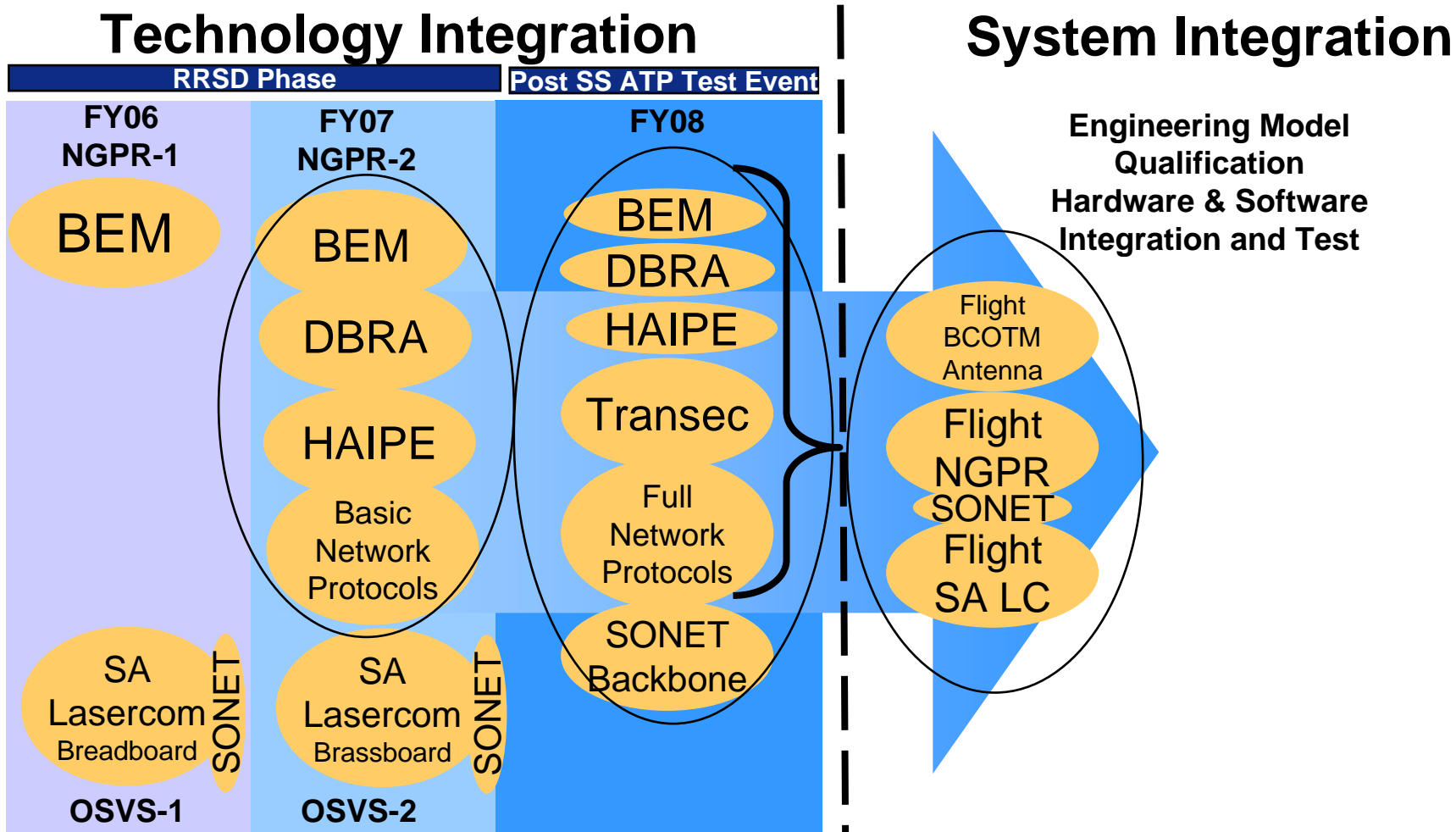
- Independent test assets
 - Network, RF, Optical, and High-Speed Electronics Test Systems
 - Operate stand-alone or as part of integrated infrastructure
- Government test team
- Government assessment of functionality/performance



Independent test capability for Government technology performance assessment



Next Steps in Technology Maturation



Higher risk integration prior to SS ATP, lower risk afterward



Back Up



- **MILSATCOM history**
 - Continual expansion by leveraging the latest technology
- **Space systems development**
 - Need to balance technology risk versus performance
 - Disciplined technology maturation is essential
- **Transformational communications success hinges on successful technology maturation**
 - Technology demonstration on track to TRL-6
 - More maturity and integration planned for the future



TSAT System

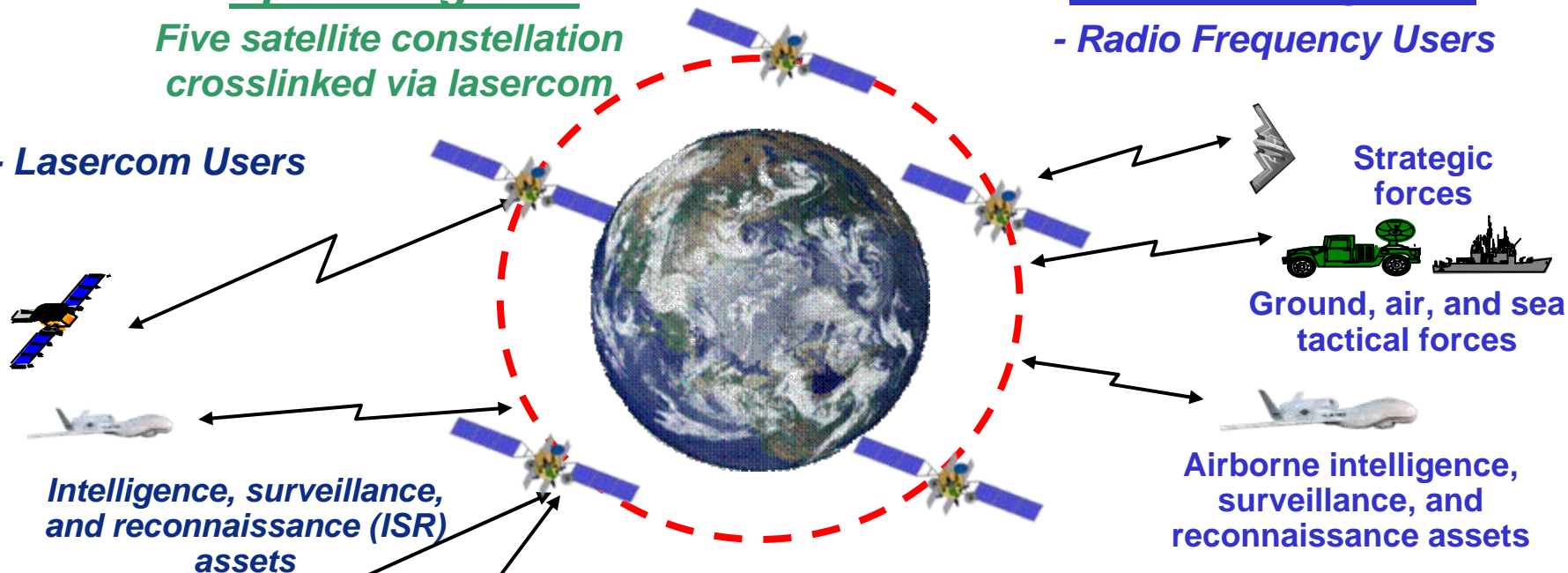
Space Segment

Five satellite constellation
crosslinked via lasercom

Terminal Segment

- Radio Frequency Users

- Lasercom Users



Intelligence, surveillance,
and reconnaissance (ISR)
assets

Strategic
forces

Ground, air, and sea
tactical forces

Airborne intelligence,
surveillance, and
reconnaissance assets

Mission Operations Segment TSAT Mission Operations System (TMOS)

Satellite
operations control

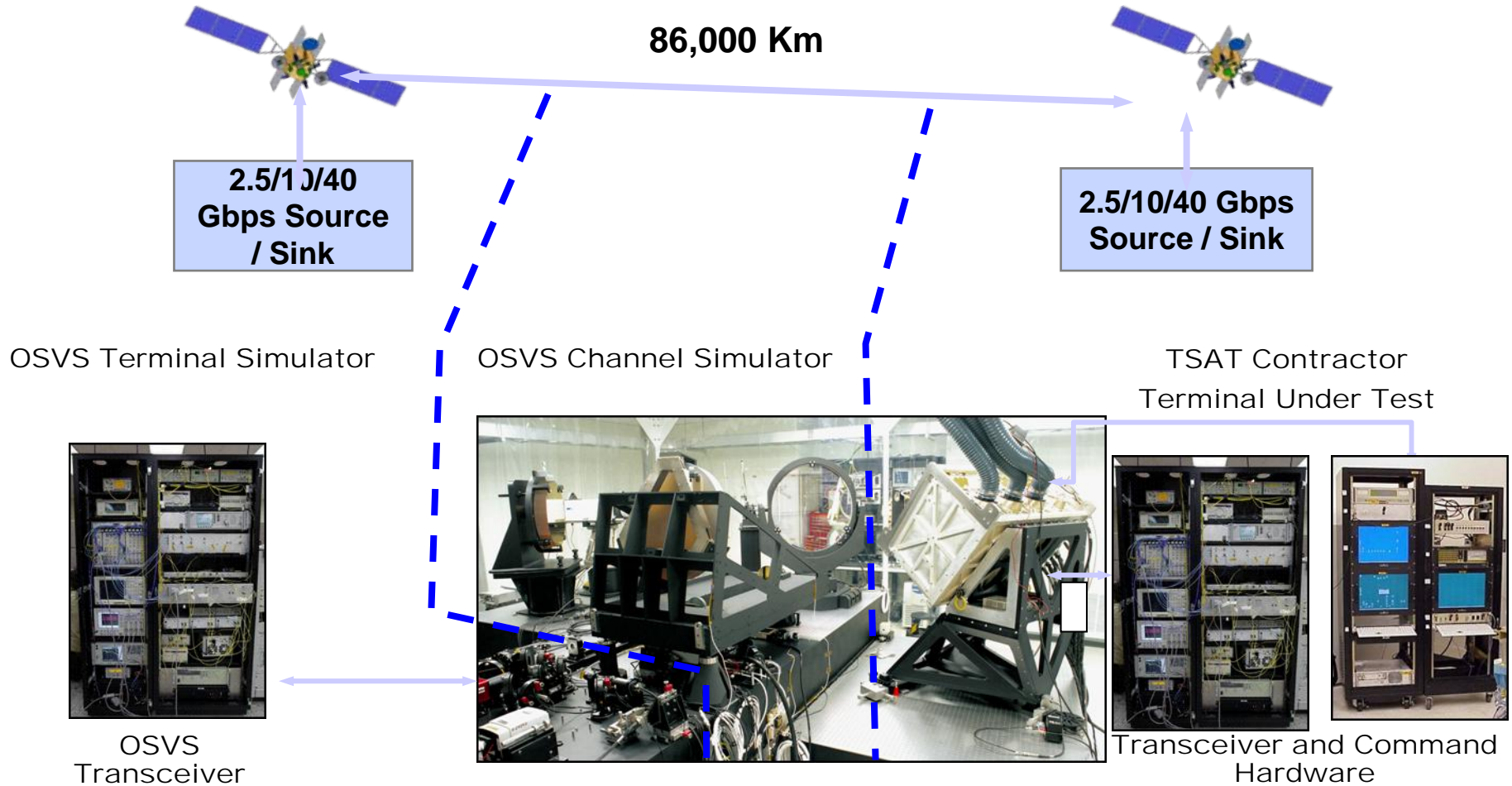
Gateways

Network & Operations management

Links to DoD, and intelligence community
Global Information Grid (GIG) infrastructure



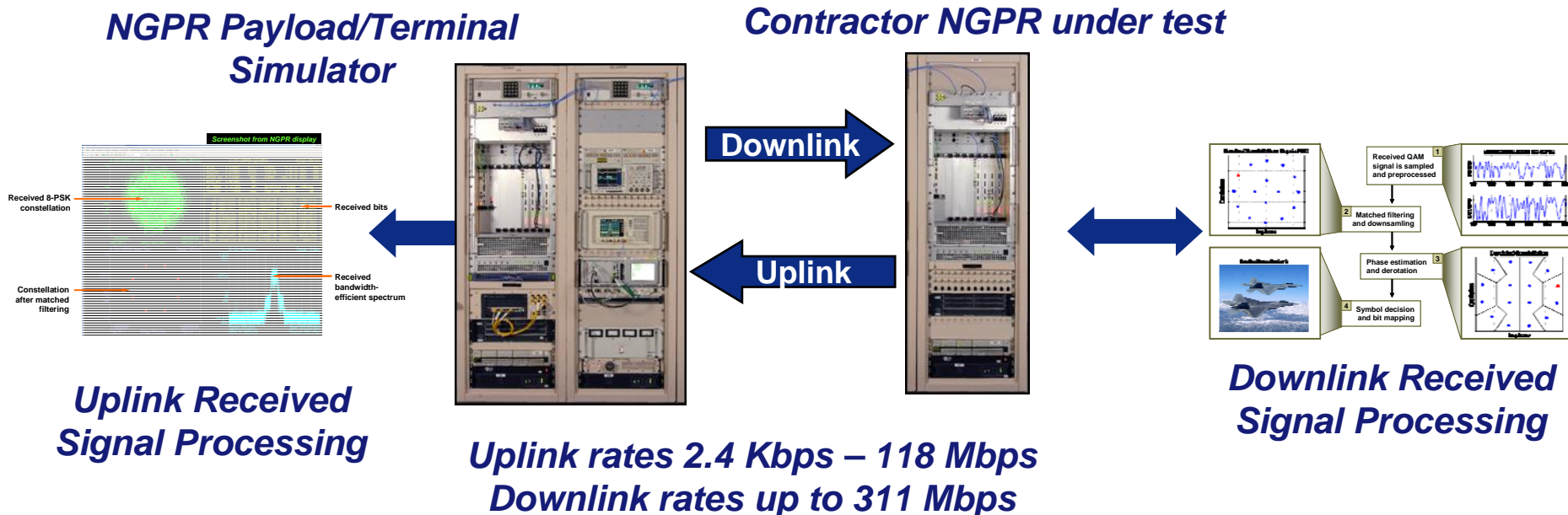
LCT-2 Free Space Communications Testing Complete: Feb 07



Independent testing of LM-NGST and BSS terminals accomplished on schedule



NGPR-2 Bandwidth Efficient Modulation (BEM) Testing Complete: Feb 07









- **Four new TSAT modulation / coding pairs for XDR+ provide more throughput in fixed bandwidth**
 - Enable power efficiency and interference protection
 - Allow multiple users to share a single band

**Testing Network communications with TSAT XDR+
uplink/downlink waveform**



WGS vs. AEHF vs. TSAT

		WGS Per Satellite	AEHF Per Satellite	TSAT Per Satellite
	BCOTM* 1' Antenna	--	COTP--140 links @ 32 Kbps↑ 256 Kbps↓	300 links*** @ 1544 Kbps
	AISR High Resolution	2 links @ 274 Mbps	--	6 links @ 311 Mbps
	AISR Hyperspectral	--	--	6 links @2448 Mbps**
	Space Based ISR	--	--	Up to 10 Gbps
	Connectivity	Pt to Pt to multipoint	Pt to Pt to multipoint	Full mesh—anyone to everyone
	Strategic	--	Yes	Yes

* Battle Command on-the-Move (BCOTM) includes network core services, such as Voice, VTC, Broadcast Imagery, Web-based Traffic

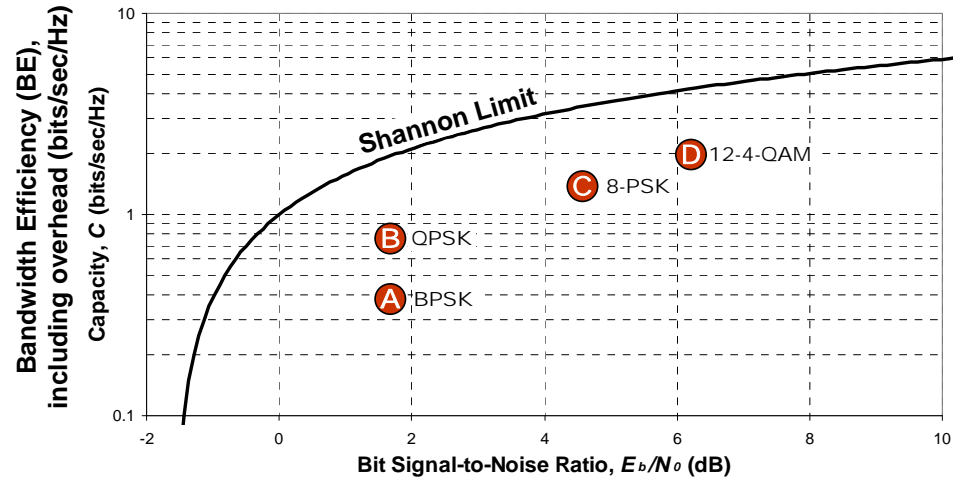
* Overall constellation available laser links

*** TSAT router enables BCOTM urban operations



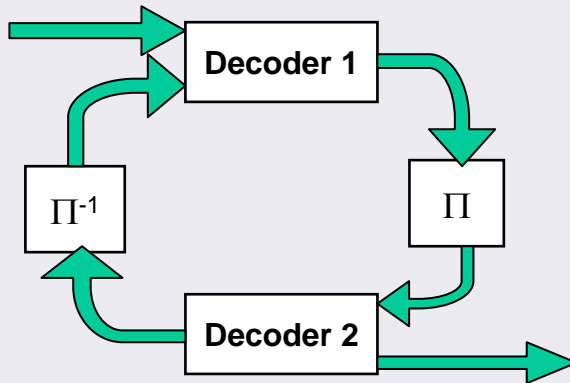
Protected Bandwidth Efficient Modulation (PBEM)

- Four new TSAT (XDR+) modulation / coding pairs provide more throughput in fixed bandwidth



Iterative Decoding and Interleaving

Enable power efficiency and interference protection



Timing and Hop Framing

Allow multiple users to share a single band



Comm accesses
 Time probe accesses

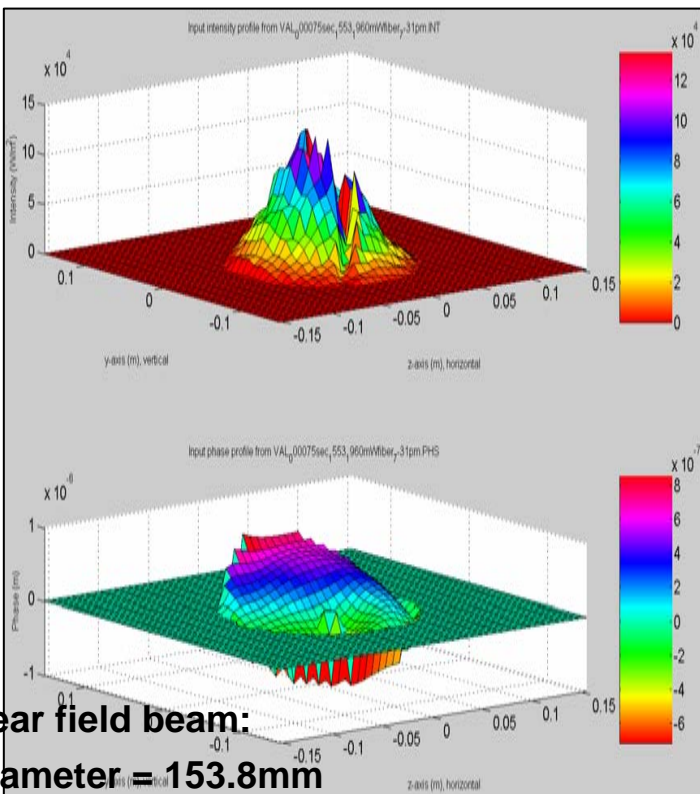


OSVS Test Result Example

Data Shown Taken on LL Terminal

WFS Data Yielding
Radiant Intensity

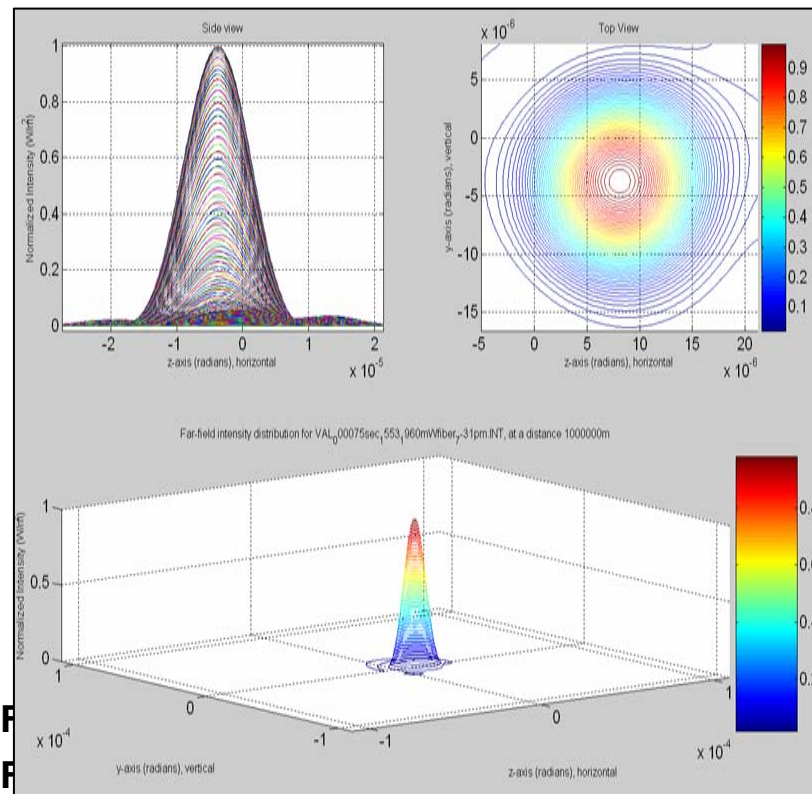
Narrow Beam of Source



**Near field beam:
Diameter = 153.8mm**

Rms wfe (tilt removed) = 0.053λ rms

Note: 12-inch relay used



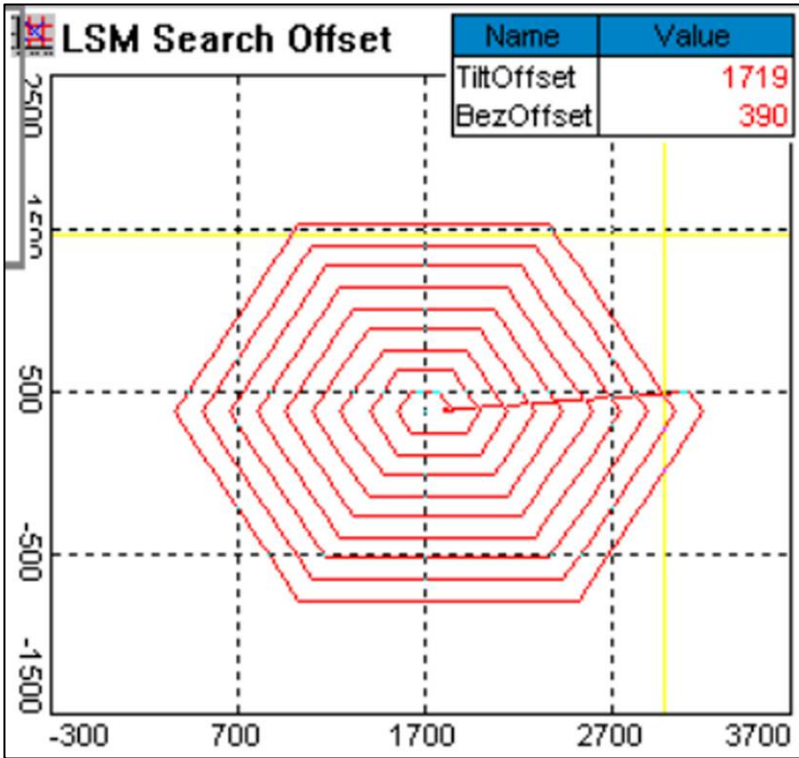
1/e² radius = 9.30μrad



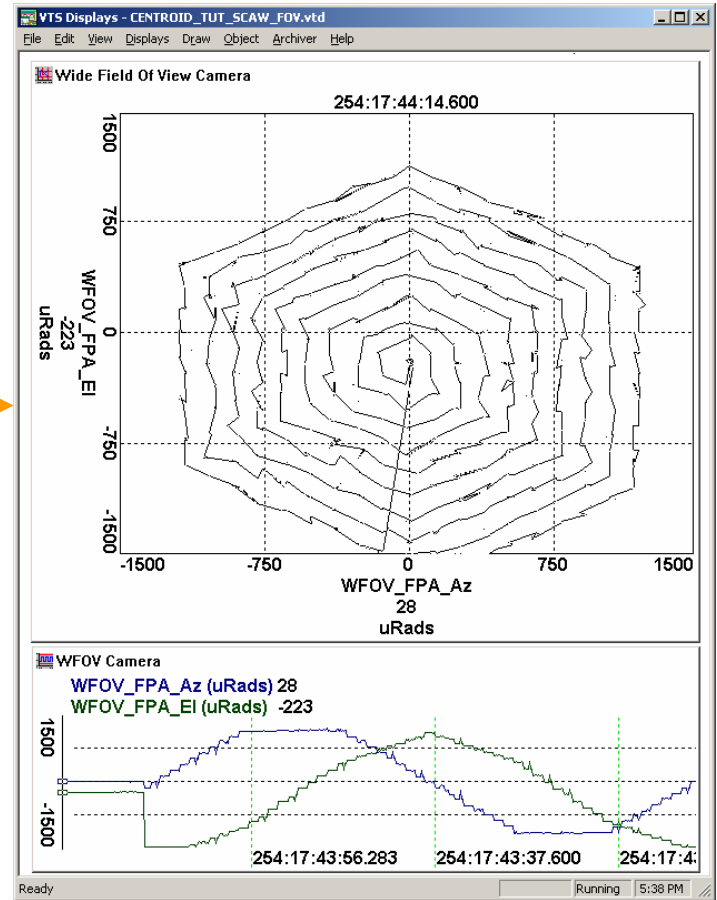
PAT Telemetry Displays Used in TUT Testing

Example Data Shown Taken on LL Terminal

TUT Mirror Commanded



OSVS Observed



Ability to measure μ rad scans demonstrated



TSAT Space and Terminal Synchronization

	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TSAT					★	★		★	★	★				
Legacy AEHF Terminals	562	666	762	731	742	742	737	683	658	606	563	533	529	529
TSAT Terminals (XDR+ and/or Ka Proc.)			129	448	756	1152	1375	1678	2129	2964	3733	4385	4728	5017
Lasercom														



Data Call: POM08
Current as of: 3/7/2007



- Terminal fielding based on Services POM08 plans (Fall 2006)
- Terminal fielding numbers represent the cumulative number of terminals from all Services
- At TSAT IOC in FY17, 742 AEHF terminals and 1152 TSAT terminals fielded
 - Issues: HC3 COTM not synchronized with TSAT, no plans for Airborne Lasercom Terminal